Signals and Circuits

ENGR 35500

Diodes

Chapter 16: From 16-1to 16-4 (pp. 720-744)

Text books:
Floyd, T. L., and Buchla, D. M., *Electroics Fundamentals: Circuits, Devices & Applications*, 8th Edition, Pearson, 2009.

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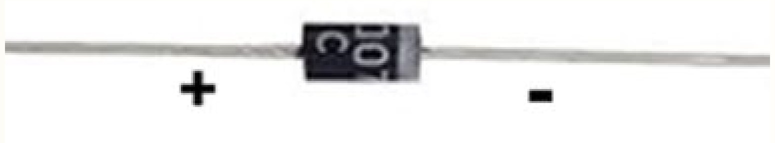
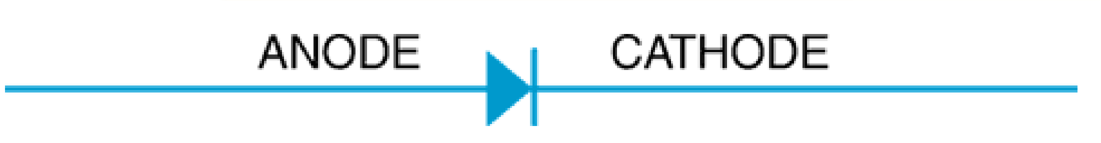
Diode

a semiconductor device with two terminals, typically allowing the flow of current in one direction only.





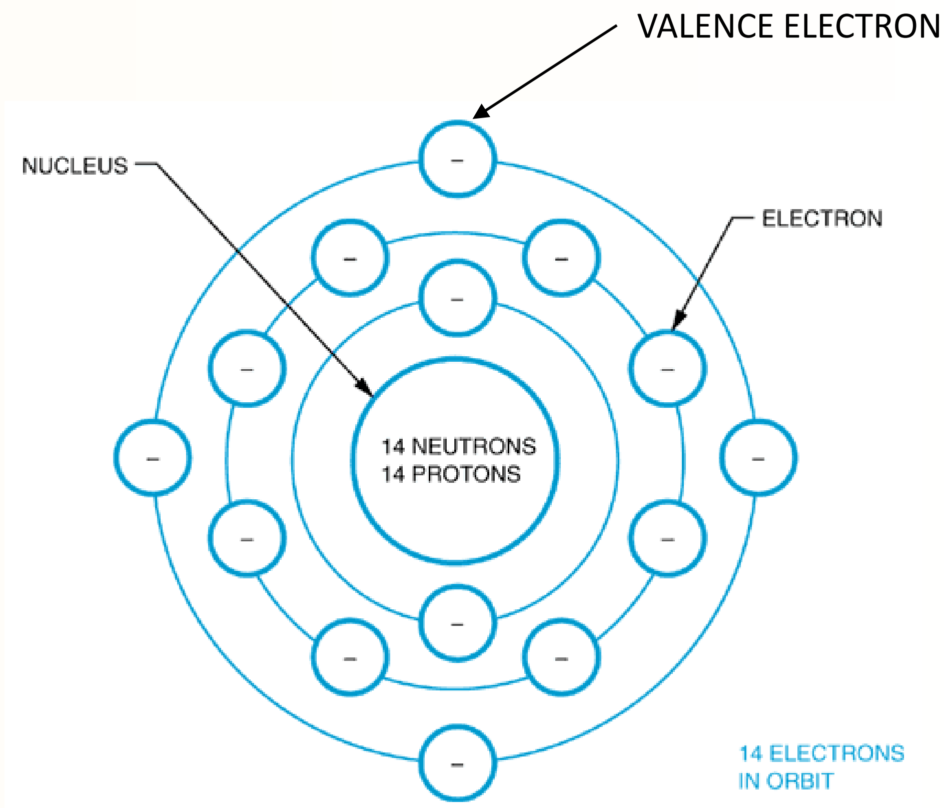
A junction diode is created by joining N- and P-type semiconductive materials together.

Semiconductive materials

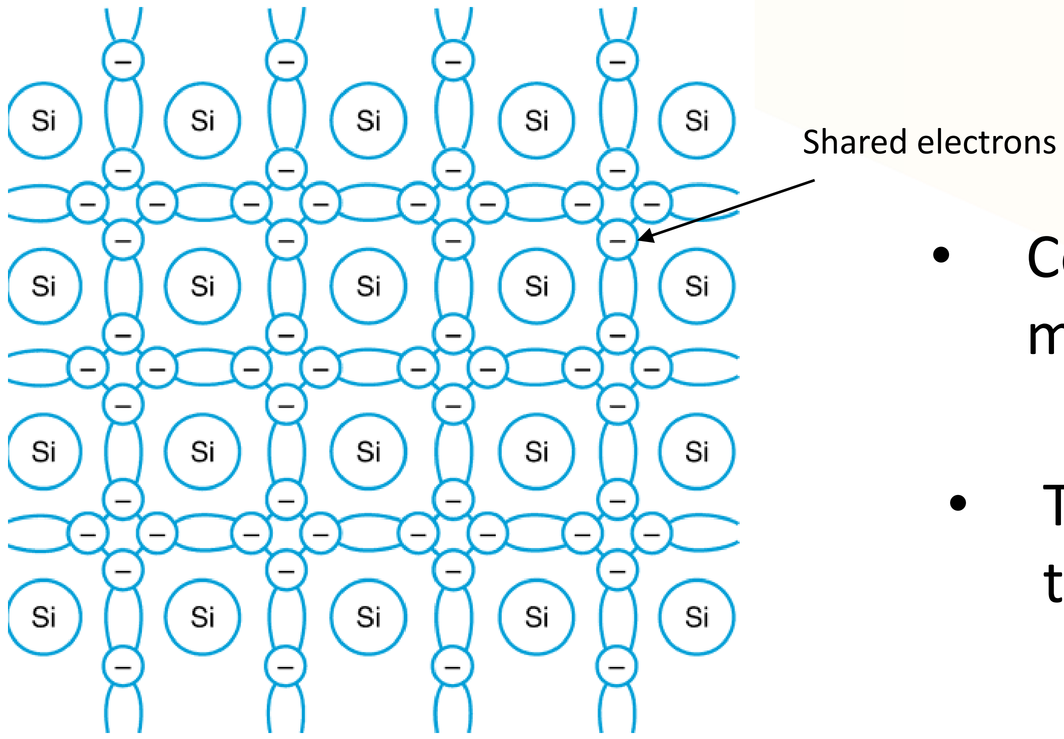
- Characteristics of semiconductive materials
  - Electrical characteristics fall between those of insulators and conductors.
  - They are not ohmic materials
  - They have negative temperature coefficients.
- There are three pure semiconductor elements:
  - Carbon (C).
  - Germanium (Ge).
  - Silicon (Si).

Semiconductive materials

- Valence electrons is in the outer (valence) Shell.
- There are usually four valence elections in the atom of semiconductive materials



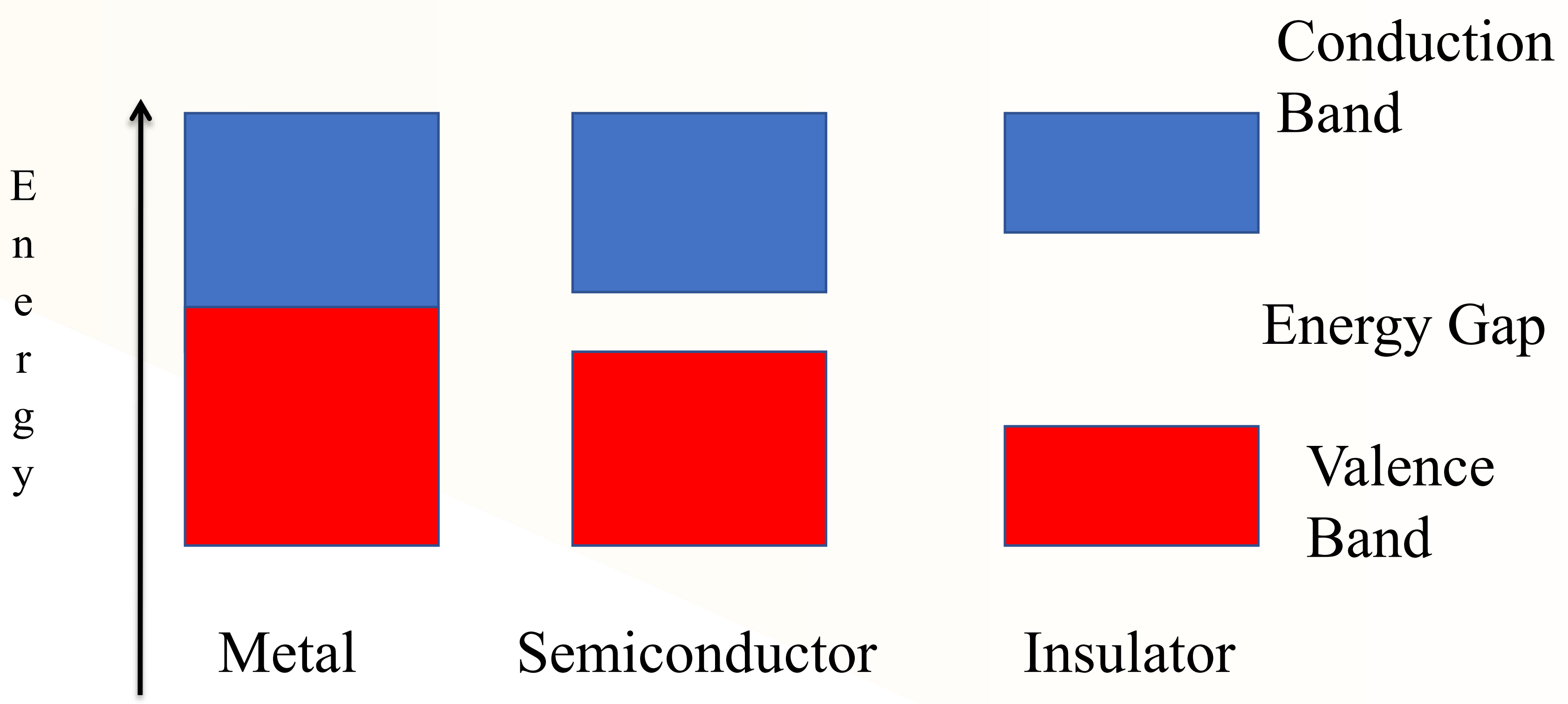
Silicon atom



Silicon bonding diagram

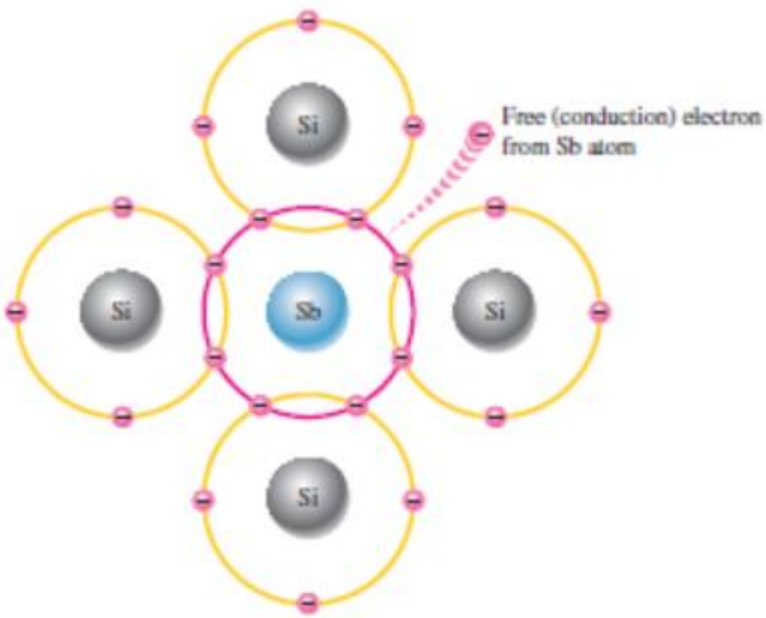
- Certain atoms combine to form a solid materials in a fixed pattern, called crystal.
- The atoms within the crystal are held together by covalent bonds.

Electronic band structure

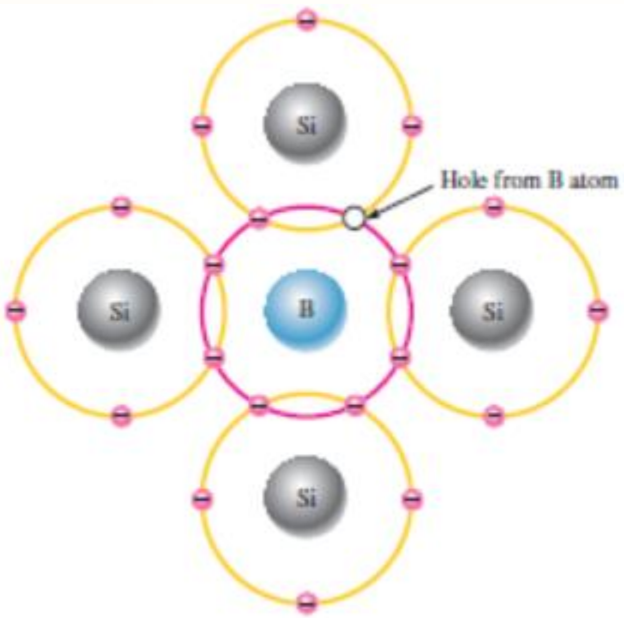


Doping

- **To increase conductivity of semiconductors, a process called doping is used.**
  - Doping is the process of adding impurities to a semiconductor material.
    - Pentavalent is made of atoms with five valence electrons.
      - Arsenic (As).
      - Antimony (Sb).
    - Trivalent is made of atoms with three valence electrons.
      - Indium (In).
      - Gallium (Ga).
      - Boron (B)



N-type semiconductor



P-type semiconductor

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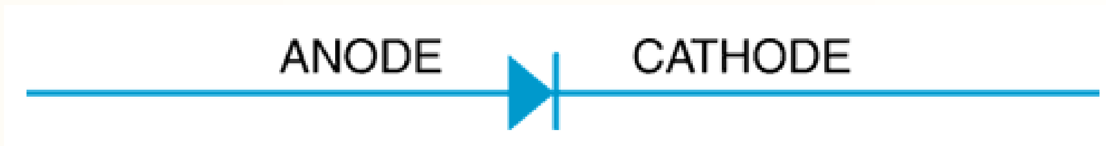
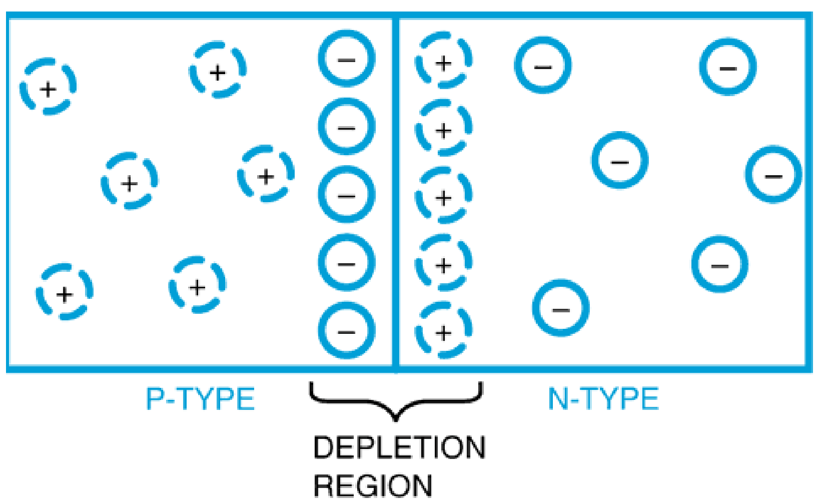
Diode

a semiconductor device with two terminals, typically allowing the flow of current in one direction only.



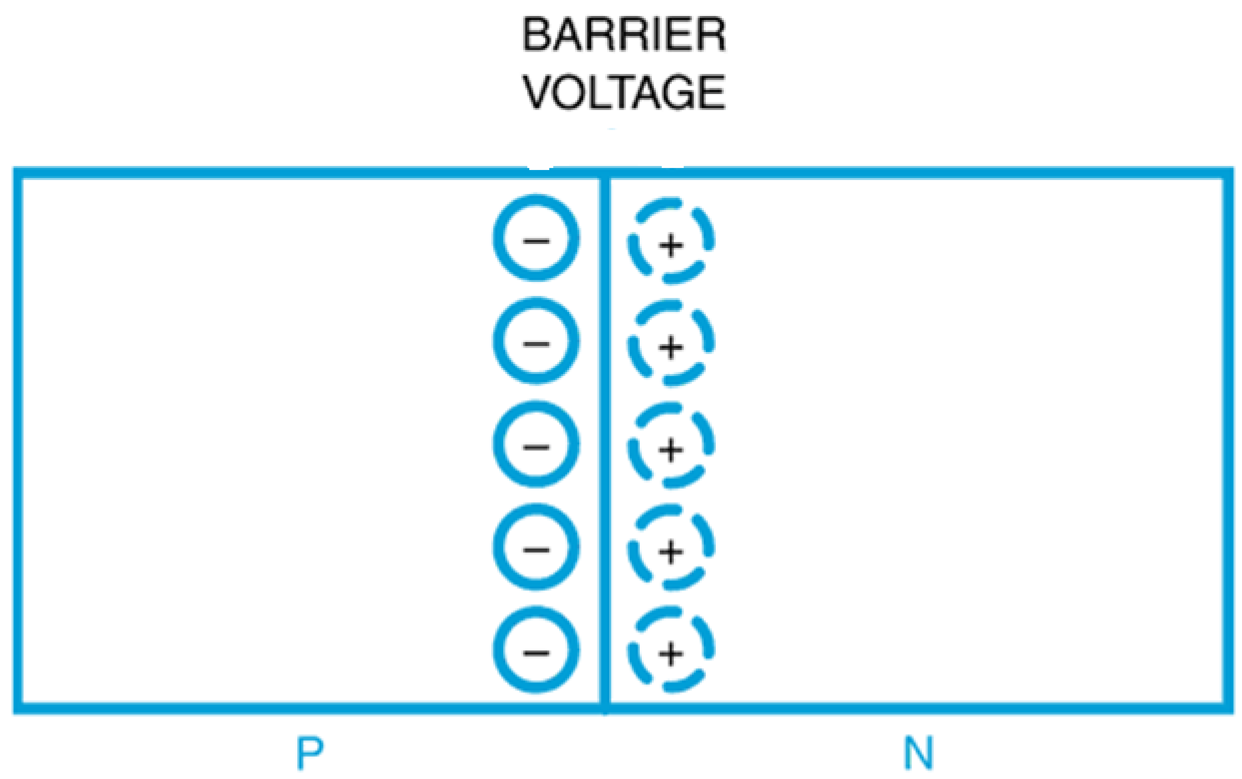
A junction diode is created by joining N- and P-type semiconductive materials together.



The depletion region is the area near the junction where electrons and holes are depleted; it extends only a short distance on either side of the junction.

Diode

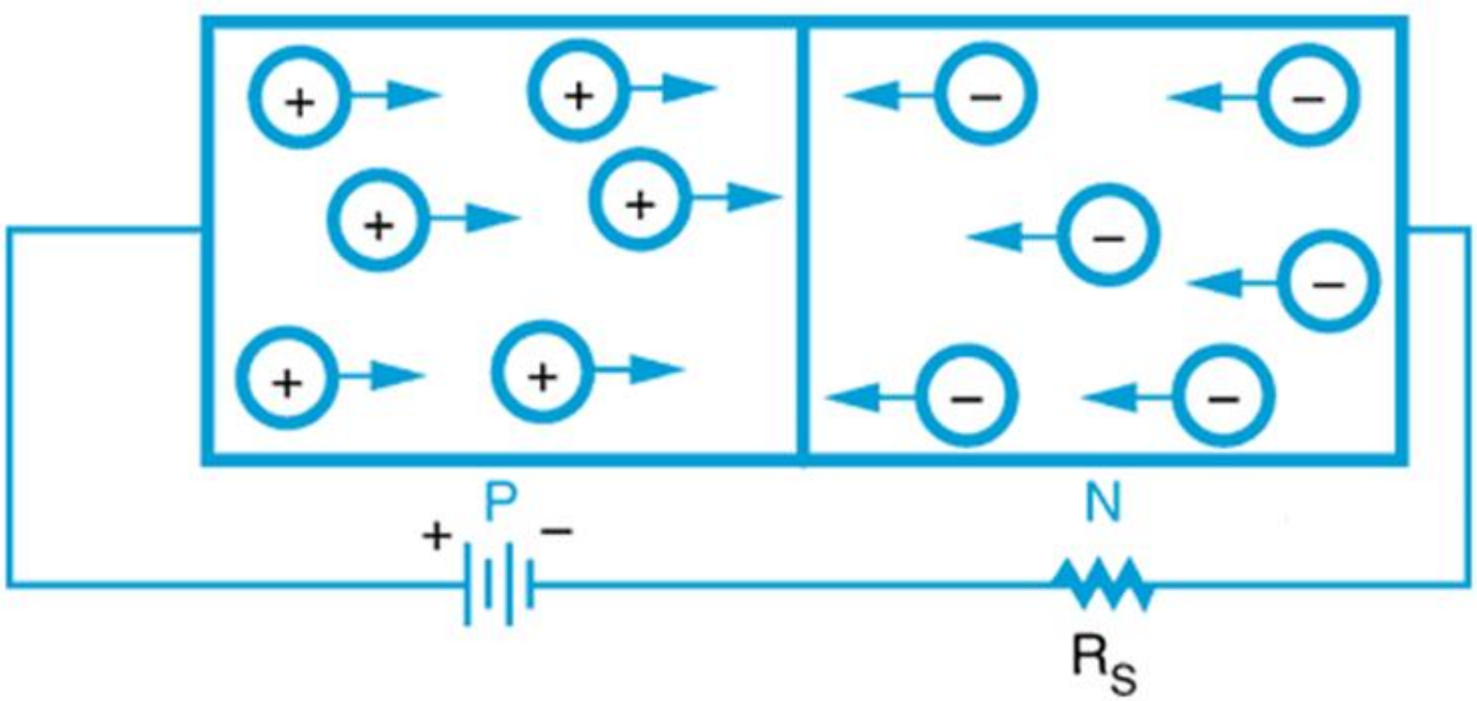
- **The barrier voltage (Barrier potential)**
  - Opposite charges that build up on each side of the junction.



Diode

➢ Bias voltage

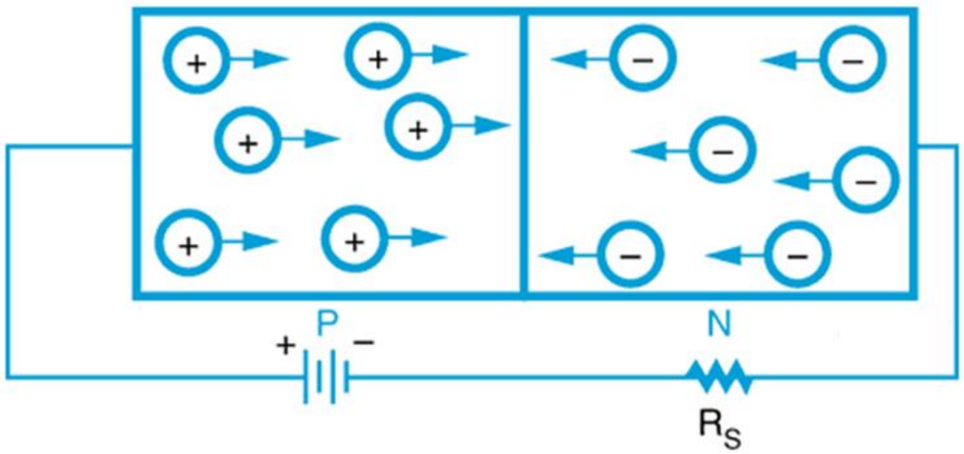
- In electronics, bias refers to use a dc voltage to establish certain operation conditions for an electronic devices;
- When a voltage is applied to a diode it is referred to as a bias voltage.



Diode

➢Forward bias

- When the electrons flow from the N-type to the P-type material, the diode has a forward bias.
  - Germanium diodes require a minimum bias flow of .3 volt.
  - Silicon diodes require a minimum bias flow of .7 volt.

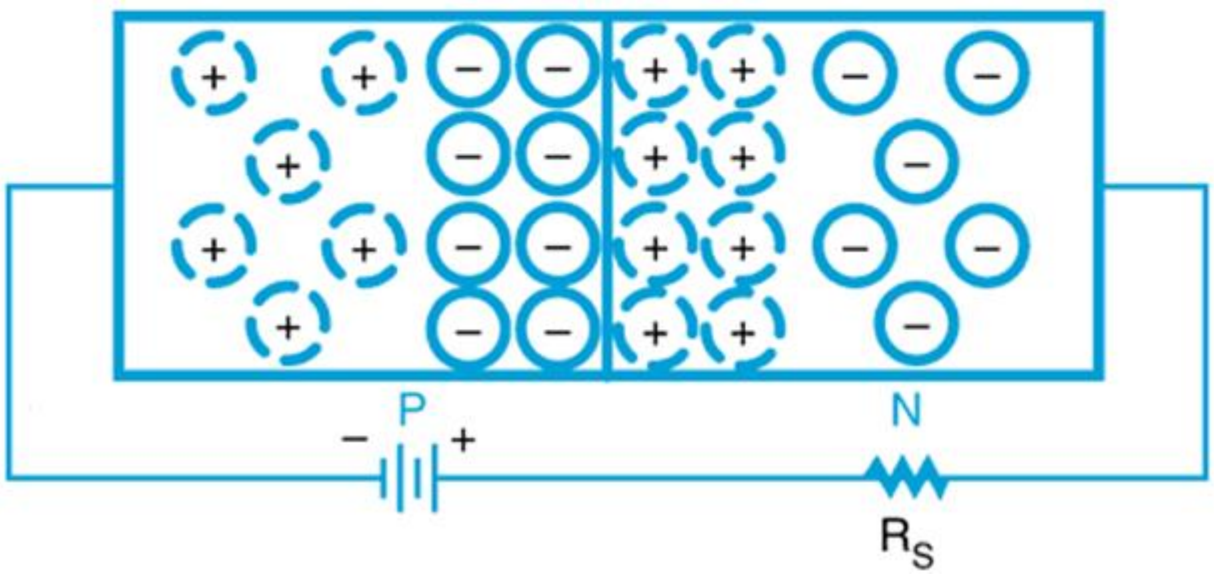


➢Forward voltage drop

- Once a diode starts conducting, a voltage drop known as a forward voltage drop occurs.
  - Voltage drop for germanium = .3 volt.
  - Voltage drop for silicon = .7 volt.

Diode

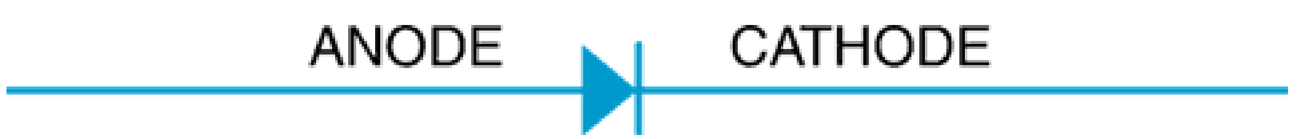
- **Reverse bias**
  - A diode where the terminals are reversed.
  - The diode does not conduct.
  - Only a small leakage current flows.



Diode

➢Diode characteristics

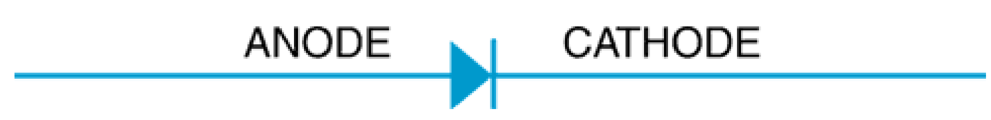
- Can be damaged by excessive heat.
- Can be damaged by excessive reverse voltage.
- At room temperature, reverse current is small.



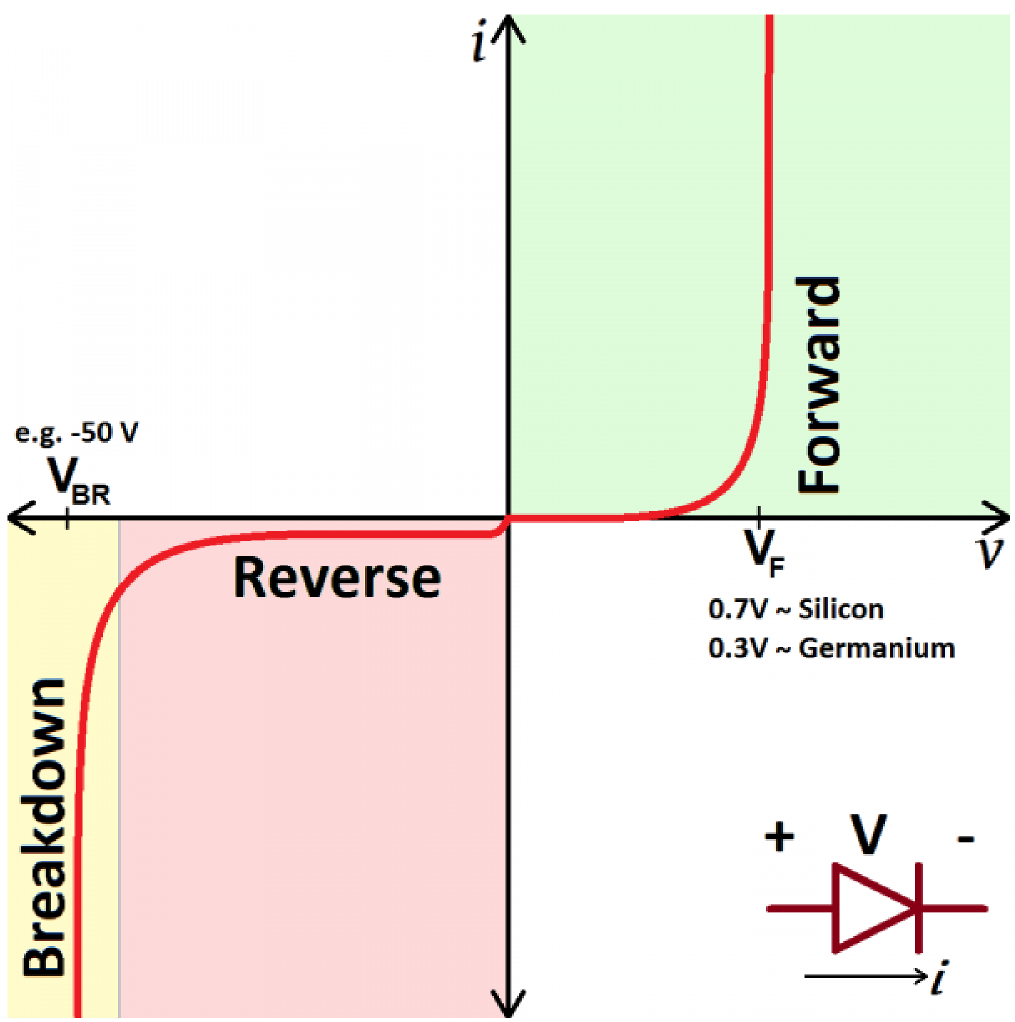
Diode

Diode characteristics

+ Forward bias -

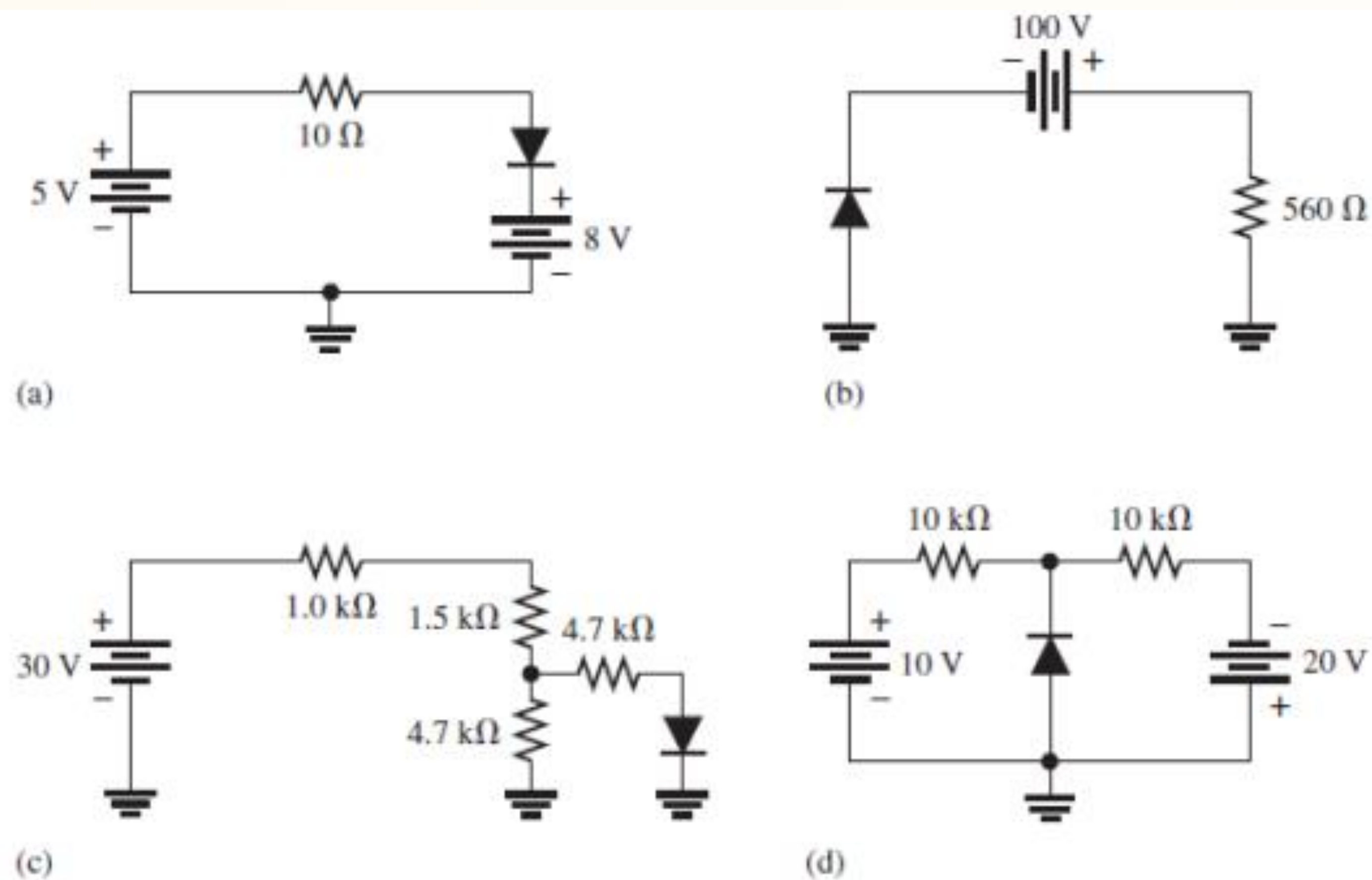


- Reverse bias +



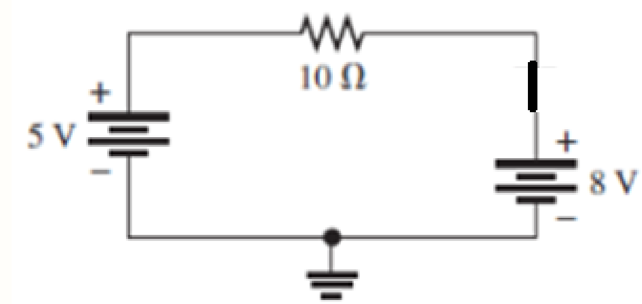
Diode

E.g. Determine the voltage across each diode.



Step 1: Make assumption

Assume the diode is on forward bias, then there is a short on the diode part



Then the current

$$I = \frac{8-5}{10} = 0.3A$$

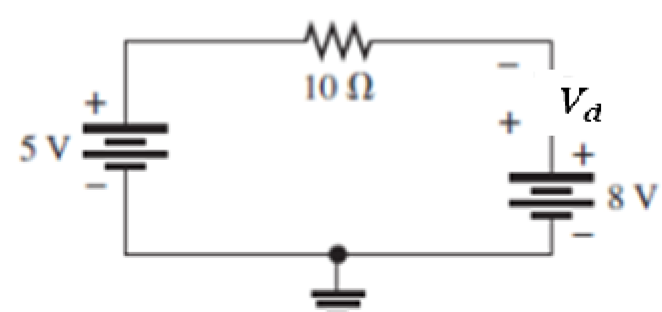
The assumed direction is counterclockwise

Step 2: Compare with the assumption

This is not consistent with the assumption, so the assumption is wrong.

Thus, the diode is on reverse bias.

Step 3: Calculate on the correct case



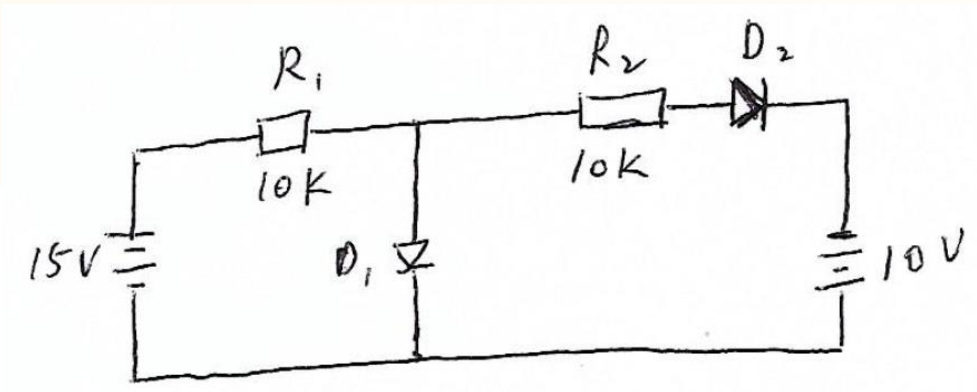
KVL $-5 - V_d + 8 = 0$

$$V_d = 3\text{V}$$

Diode

E.g.

Determine the voltage across each diode.



$$-15 + I_1 R_1 = 0$$

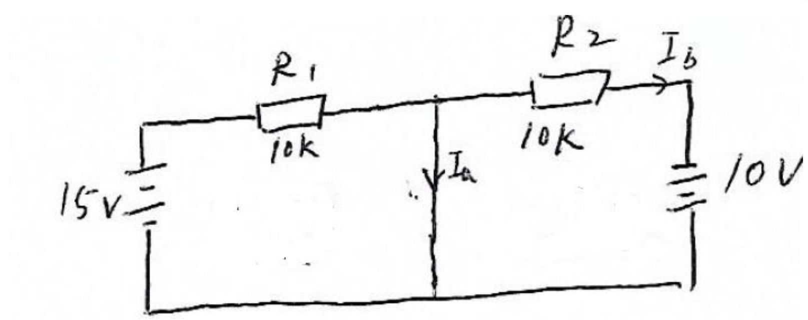
$$I_2 R_2 - 10V = 0$$

$$\Rightarrow I_1 = 1.5mA$$

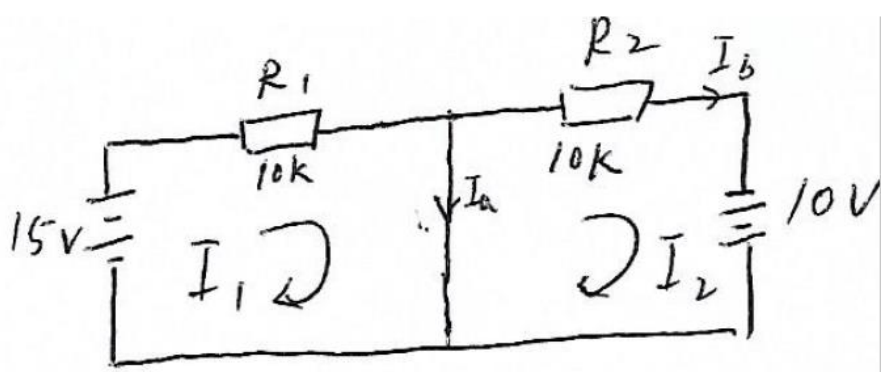
$$I_2 = 1mA$$

Step 1: Make assumption

Assume the diodes are both on forward bias, then there is a short on the diode part



Mesh analysis



The current directions are both as drawn in the figure.

$$I_a = I_1 - I_2 = 0.5\text{mA}$$

$$I_b = I_2 = 1mA$$

Step 2: Compare with the assumption

This is consistent with the assumption, so the assumption is correct.

Thus, both of the diodes are on forward bias.

Step 3: Calculate on the correct case

$V_{d1} = 0\text{V}$ or 0.3v or 0.7v

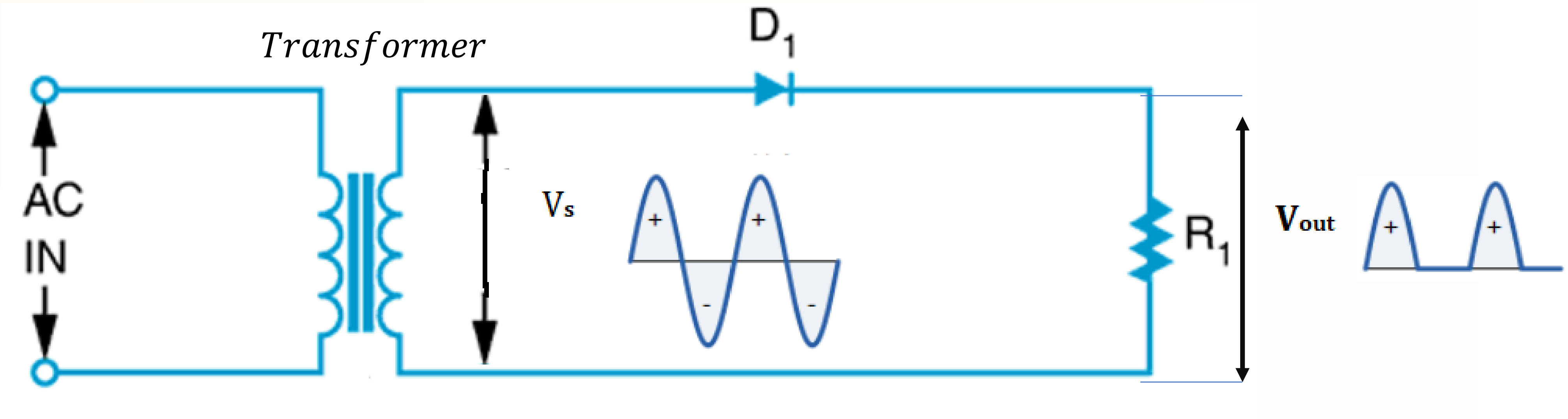
$V_{d2} = 0\text{V}$ or 0.3v or 0.7v

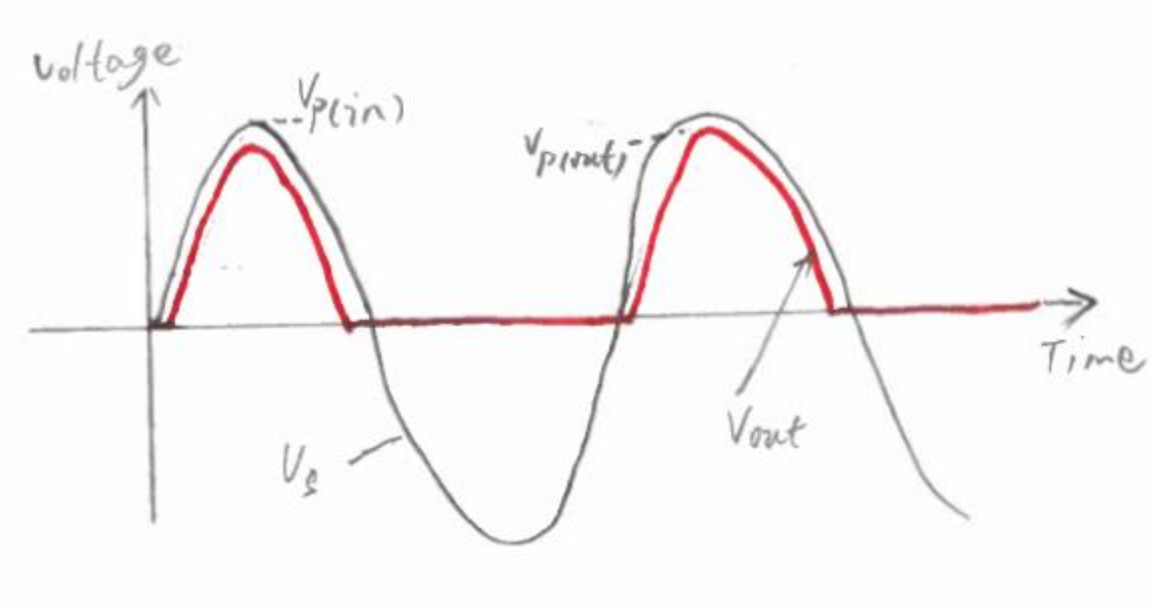
Rectifier Circuits

- ➢ The heart of the power supply.
- ➢ Converts incoming AC voltage to a DC voltage.
- ➢ Three basic types of rectifier circuits:
  - Half-wave rectifiers.
  - Full-wave rectifiers.
  - Bridge rectifiers.

Half-wave rectifiers

- Operates only during one half of the input cycle.
- Frequency is the same as the input frequency.



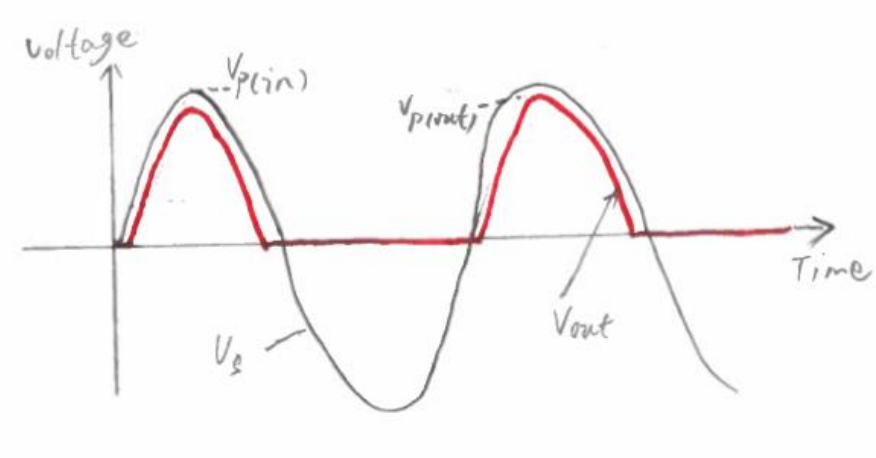


$$V_{avg} = \frac{V_{p(out)}}{\pi}$$

$$V_{p(out)} = V_{p(in)} - 0.7V$$

Half-wave rectifiers

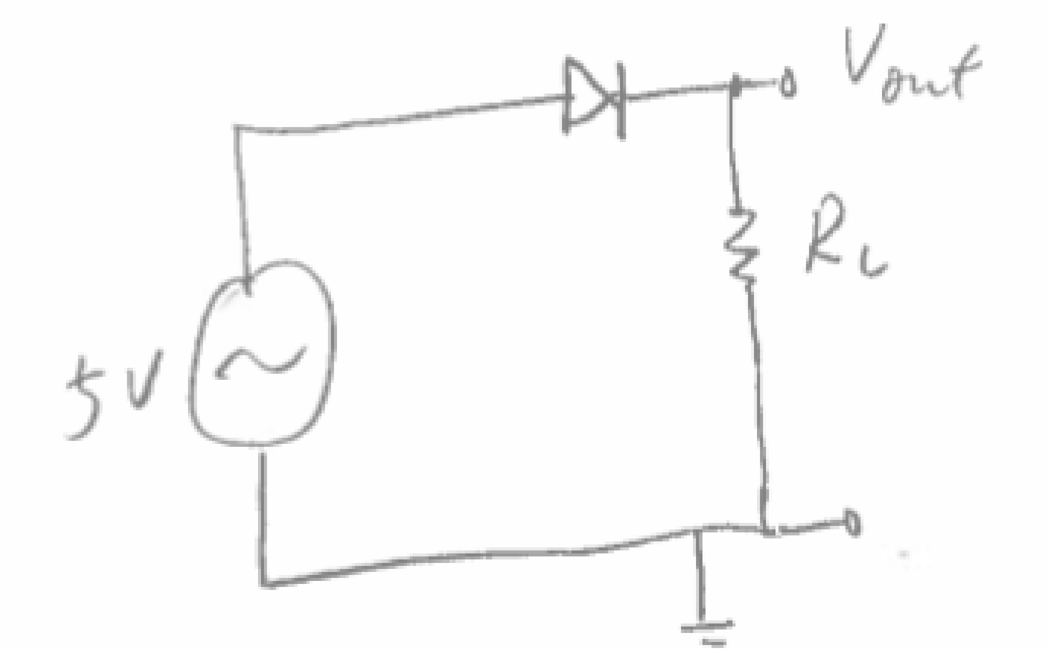
Note:



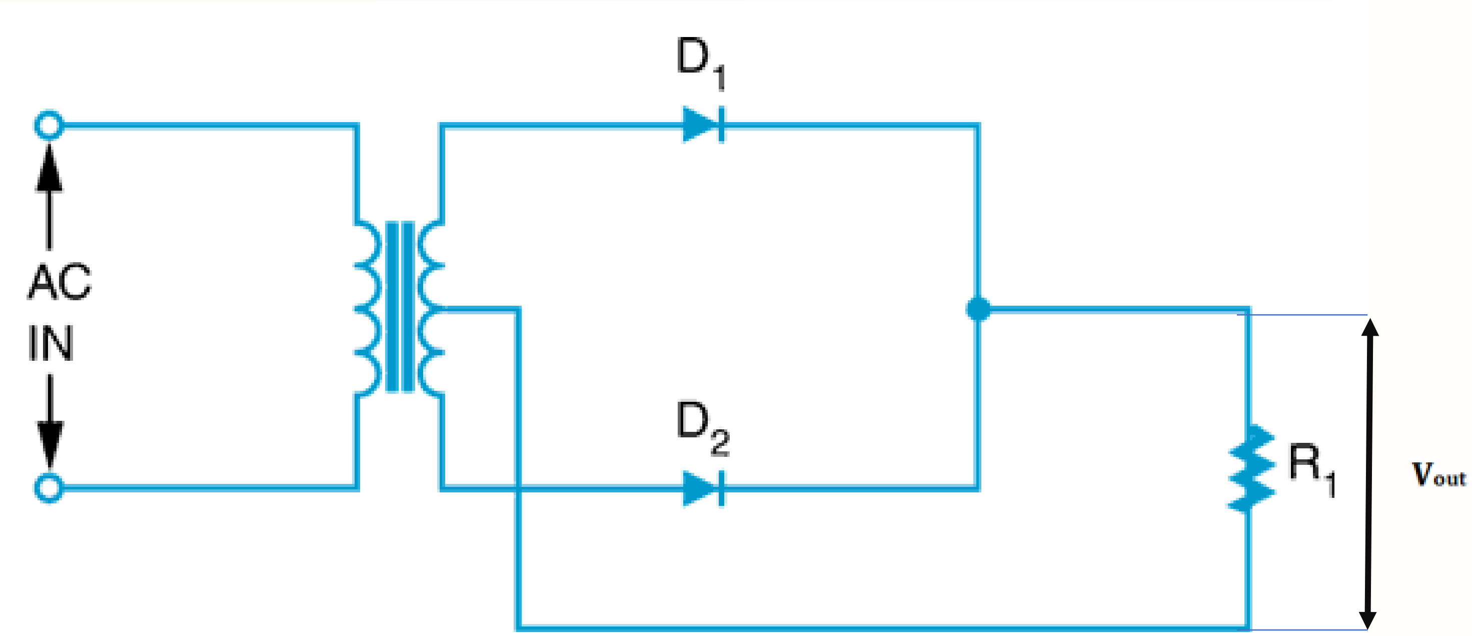
$$V_{avg} = \frac{V_{p(out)}}{\pi}$$

$$V_{p(out)} = V_{p(in)} - 0.7V$$

Determine the peak output voltage and the average value of the output voltage of the rectifier in the figure below for the indicated input voltage.

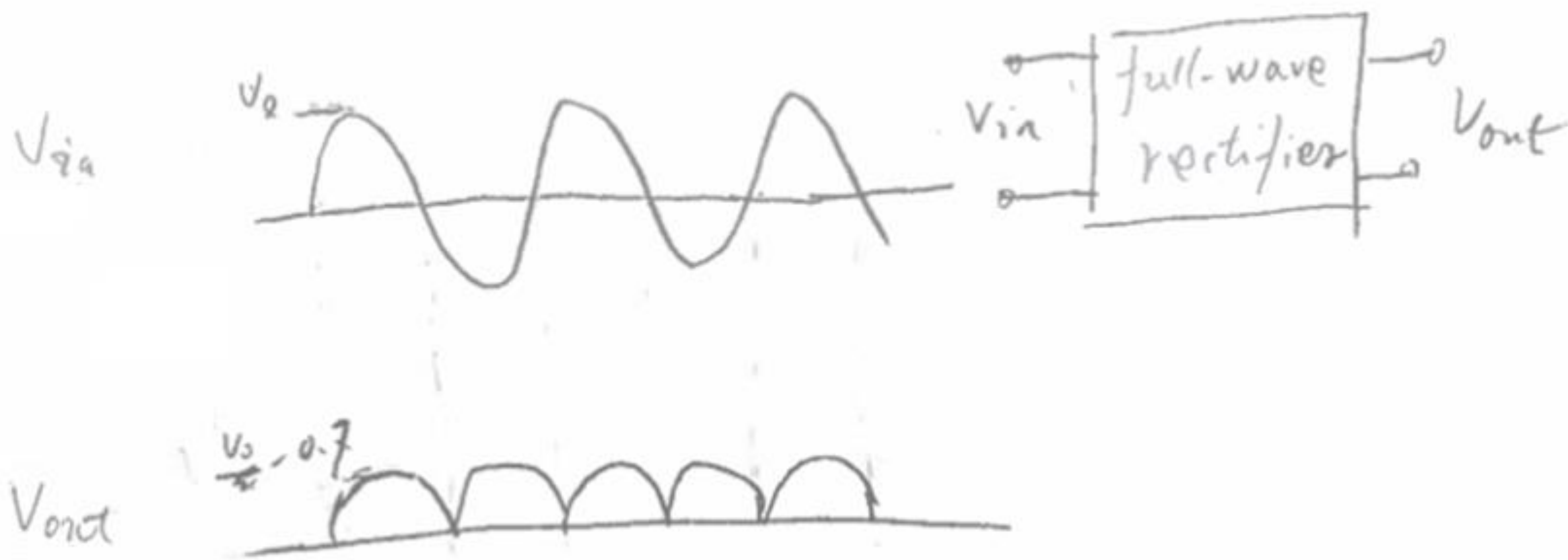


Full-wave rectifiers

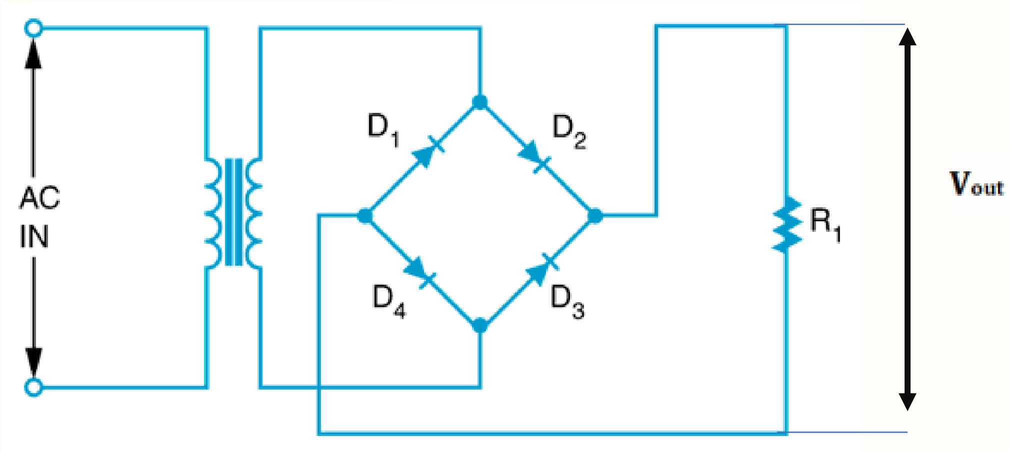


$$V_{avg} = \frac{2V_{p(out)}}{\pi}$$

$$V_{p(out)} = \frac{V_{p(in)}}{2} - 0.7V$$

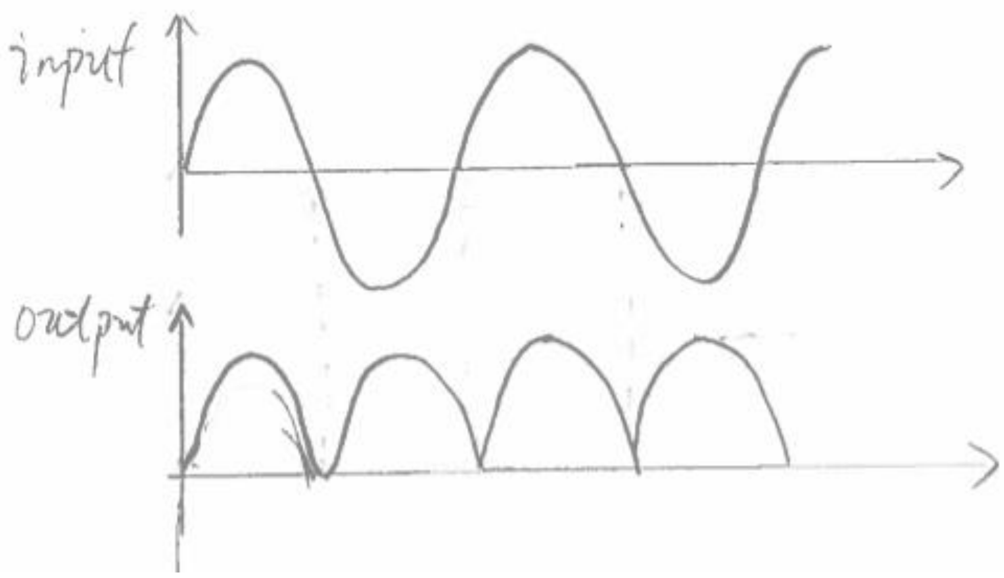


Full-wave bridge rectifier

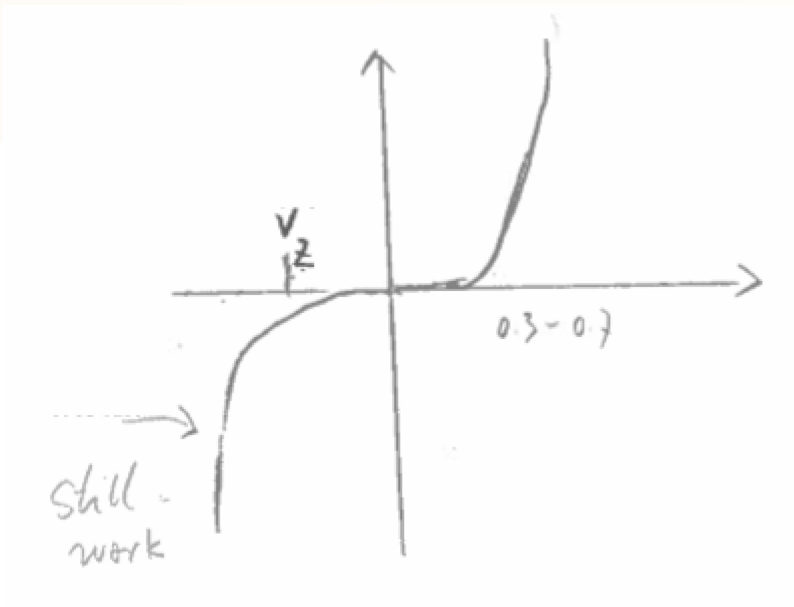


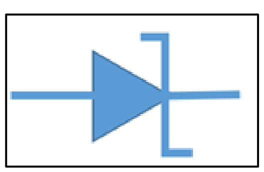
$$V_{avg} = \frac{2V_{p(out)}}{\pi}$$

$V_{p(out)} = V_{p(in)}$ - 0.7x2

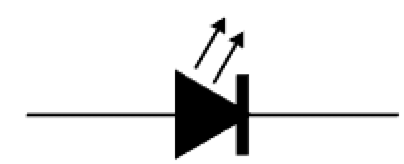


Special-purpose diodes





Zener diode



The Light-Emitting Diode (LED)